Final evaluation of nine plum cultivars grafted onto two rootstocks in a trial established in 1998 at Holovousy

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Abstract

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Nine plum cultivars newly introduced into production were evaluated in a replicated trial established in 1998 on two rootstocks planted in a spacing of 5 × 1.5 m. Trees were trained as spindles and evaluated regarding vigour, canopy performance, level and stability of yields, yield efficiency, fruit size, time of flowering and harvest season until 2010. Significant differences among cultivars were found but the most interesting were related to tree vigour, yield efficiency and fruit size. Dwarfing influence of Wangenheim seedling was negligible in Empress and Čačanska lepotica but mostly visible in Sanctus Hubertus. Wegierka Dabrowicka on both the rootstocks had the highest yield efficiency, exceeding 3 kg/m^3 of trunk cross-section area. Yield efficiency of trees grafted on Wangenheim was generally higher than those grafted on Myrobalan but the greatest difference was evidenced on Domestic Prune (more than 25%). Suggestions in terms of trees-spacing are definitively proposed upon results of this study.

Keywords: tree characteristics; harvest time; tree vigour; yields, yield efficiency; fruit size

This study was initiated with the aim to evaluate new productive cultivars and rootstocks suitable for Czech climatic conditions and able to produce high quality fruit for a longer seasonal period (Grzyb, Hartman 1995; Paprštein, Blažek 2003; Kosina 2004; Blažek, Kneifl 2005; Gonda 2006).

In the last few decades, a large number of new plum cultivars have arisen. These new cultivars, combined with a suitable system of training, could be a proper basis for modern intensive orchards. Every cultivar used in different sites must be well adapted to local environmental conditions, which is an important factor in successive growing. Therefore, cultivar testing plays an important role in current plum research (Kemp et al. 1994; Hartmann 1998, 2007; Michels, Kirchmann 2002; Stehr 2003).

For modern plum production, new rootstocks should reduce tree vigour, have good grafting-compatibility with several plum cultivars, good tolerance to major diseases and pests, and appear thornless (Botu et al. 2007). Plum trees growing on dwarfing or semi-dwarfing rootstocks like Citation, Pixy and St. Julien A have evidenced sometime problems with a lower tree survival, lower yield efficiency and smaller fruits in comparison to trees grafted onto vigorous rootstock (Masabni et al. 2007).

Regular and sufficiently high yields are important factors which decide about profitability of the commercial plum growing. Plum production in the Czech Republic is profitable at present time if yields reach about 15 t/ha (Blažek, Pištěková 2006).

Cultivars whose yields and fruit size are less dependent upon climatic conditions of the year can be preferably recommended for commercial growing (Liverani et al. 2010).

The present paper reports on the final results of new plum cultivars grafted onto two rootstocks in

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an orchard trial that was established in Holovousy, Czech Republic, in spring 1998. Some preliminary results from this trial that were mainly focused on different aspect of the rootstocks effects, were published (Blažek et al. 2004–2006).

MATERIAL AND METHODS

Nine cultivars (Bluefree, Čačanska lepotica, Čačanska rana, Domestic Prune, Empress, Herman, Sanctus Hubertus, Valor and Wegierka Dabrowicka) were evaluated in a trial established in 1998 in RBIP in Holovousy. The rootstocks adopted were Myrobalan (*Prunus cerasifera* L.) and Wangenheim Prune seedling (*Prunus domestica* L.) and lasted for 10 cropping seasons till 2010. One-year-old nursery trees obtained after summer budding were planted in three blocks (replications) for each rootstock with a spacing of 5 × 1.5 m within and along the rows, respectively. For each replication of cultivar and rootstock, 3 trees were used.

Climatic conditions at Holovousy are characterised by the average annual temperature of 8.1°C and the average annual rainfall of 650 mm. The soil was medium sandy loam with a rather deep cultivated layer on gravely substrate. The orchard was located at the altitude of 280 m a.s.l. and it was situated on a very gentle slope facing to north.

Orchard management was based on using mown grass kept in driveways and herbicide strips (1.5 m) based upon application of contact herbicides along the rows of trees. Trees were trained as spindles using wooden stakes as supports at the beginning to help in the process of tree canopy training in the first years. No irrigation was applied in the orchard. Spraying treatments against pests and diseases were conducted according to the recommendations for commercial orchards.

The following records were taken annually: canopy diameter (in two opposite directions), canopy height, trunk cross-sectional area, yields per tree and fruit weight. In some years, several special canopy characteristics were recorded mostly based upon 1–9 numeric descriptors: canopy density (1 – very dense; 9 – very thin), branch spurring (1 – no spurs; 9 – abundant), branch bare area (1 – very large; 9 – no bare area) and branch setting angle (deflection angle from vertical level). The average fruit weight was estimated based upon weighing of 50 fruits randomly sampled from each replication.

Data were statistically evaluated by analysis of variance (ANOVA).

Relationships between specific yields and mean fruit weights were tested by simple correlation analysis within each cultivar and rootstock combination using mean year values of these characteristics from total period of their evaluation.

RESULTS

Tree vigour

On the majority of cultivars, vigour differs significantly on both rootstocks (Table 1). The most vigorous were the trees of cv. Sanctus Hubertus grafted onto Myrobalan rootstock. As related to cultivar, the

Table 1. Tree vigour according to cultivars and rootstocks

Cultivar	Year when final canopy volume was achieved		Final trunk cross-sectional area (cm^2) in 2010		Sequence of cultivars according to tree vigour		Vigour reduction due to Wangenheim rootstock used
	Myrobalan	Wangenheim	Myrobalan	Wangenheim	Myrobalan	Wangenheim	(%)
Bluefree	2002	2005	70.6	46.6	9	9	34.0
Čačanska lepotica	2003	2004	101.0	86.8	4	1	14.1
Čačanska rana	2002	2004	120.6	83.3	2	2	30.9
Domestic Prune	2003	2005	94.8	61.4	5	8	35.2
Empress	2004	2005	84.3	76.5	8	4	9.2
Herman	2002	2004	117.4	82.4	3	3	29.8
Sanctus Hubertus	2002	2004	136.9	63.7	1	7	53.5
Valor	2003	2004	84.8	70.1	7	5	17.2
Wegierka Dabrowicka	2005	2006	90.2	67.3	6	6	25.3
Average	2002.9	2004.6	101.9	69.2			32.1
LSD (P = 0.05)			11.3	9.0			

Table 2. Some vegetative traits according to cultivars and rootstocks

Cultivar	Canopy density		Branch spurring		Branch setting angle		Branch bare area	
	Myrobalan	Wangenheim	Myrobalan	Wangenheim	Myrobalan	Wangenheim	Myrobalan	Wangenheim
Bluefree	6.7	6.6	3.9	3.6	75.0	83.9	4.2	4.0
Čačanska lepotica	5.9	7.0	5.3	5.0	61.3	73.3	5.6	4.7
Čačanska rana	3.1	3.4	6.8	6.5	65.9	59.3	6.8	6.8
Domestic Prune	3.0	3.0	7.0	7.0	83.0	69.9	7.0	7.4
Empress	4.0	4.0	6.5	7.0	70.0	83.0	7.5	7.0
Herman	3.5	3.6	6.8	6.4	69.2	78.0	7.2	7.0
Sanctus Hubertus	3.0	3.7	7.1	6.9	65.6	77.1	8.0	6.7
Valor	3.4	3.7	7.0	7.3	70.0	83.0	6.8	7.7
Wegierka Dabrowicka	3.4	3.0	6.6	7.2	83.0	68.7	7.0	7.5
Average	4.3	4.1	6.1	6.2	71.4	75.1	6.4	6.5
LSD (P = 0.05)	1.3	1.3	1.2	1.2	3.1	3.4	1.3	1.2

most vigorous was Čačanska rana followed by Herman. Čačanska lepotica grafted onto Wangenheim rootstock showed the strongest tree growth.

The least vigorous on both rootstocks were trees of Bluefree cv. followed by Empress and Valor grafted onto Myrobalan rootstock. As regards the general rootstock effects, the vigour of trees grafted onto Wangenheim was almost one third of the vigour of trees grafted onto Myrobalan. Its dwarfing influence was rather negligible in Empress and Čačanska le-

Table 3. Annual and cumulate yield per tree, yield per hectare, yield efficiency according to cultivars and rootstocks

Cultivar	Rootstock	Mean annual yield/tree (kg)			Harvest/tree (kg)	Mean annual yield (t/ha)		Mean annual specific yield (kg.m^3)	
		Ø 2001–2010	min	max	Σ 2000–2010	Ø	t max	Ø	t max
Bluefree	Myrobalan	9.1	5.2	16.7	96.7	12.1	22.3	1.5	2.8
	Wangenheim	8.6	5.1	16.7	90.6	11.5	22.3	1.6	2.7
Čačanska lepotica	Myrobalan	9.9	1.5	23.1	99.3	13.2	30.8	1.6	3.3
	Wangenheim	10.6	1.9	21.9	106.5	14.2	29.2	1.9	3.5
Čačanska rana	Myrobalan	10.2	0.4	24.0	102.1	13.6	32.0	1.4	3.4
	Wangenheim	7.9	1.0	21.3	79.1	10.5	28.4	1.2	2.9
Domestic Prune	Myrobalan	10.8	2.1	26.1	107.8	14.4	34.7	1.6	3.8
	Wangenheim	12.2	2.4	25.6	121.9	16.3	34.1	2.1	3.8
Empress	Myrobalan	13.5	7.5	23.5	136.7	18.0	31.3	2.3	4.1
	Wangenheim	10.7	4.2	20.9	110.5	14.3	27.9	2.3	4.2
Herman	Myrobalan	11.3	1.6	21.2	113.1	15.1	28.3	1.7	2.6
	Wangenheim	10.8	1.5	22.0	107.9	14.3	29.3	1.8	3.5
Sanctus Hubertus	Myrobalan	12.0	3.6	22.2	120.0	16.0	29.6	1.7	3.0
	Wangenheim	11.5	3.3	20.7	115.2	15.4	27.6	2.0	4.0
Valor	Myrobalan	15.1	0.9	39.8	153.2	20.1	53.1	2.3	5.3
	Wangenheim	13.1	6.3	30.7	134.4	17.4	40.9	2.7	5.1
Wegierka Dabrowicka	Myrobalan	14.6	5.0	26.9	147.2	19.4	35.8	3.0	4.8
	Wangenheim	13.3	0.6	25.1	135.9	17.7	33.4	3.2	5.9
Average	Myrobalan	11.8	0.4	39.8	119.6	15.8	53.1	1.9	2.8
	Wangenheim	11.0	1.6	30.7	111.3	14.6	40.9	2.1	3.3
LSD (P = 0.05)	Myrobalan	0.42			4.0			0.35	
	Wangenheim	0.39			3.7			0.33	

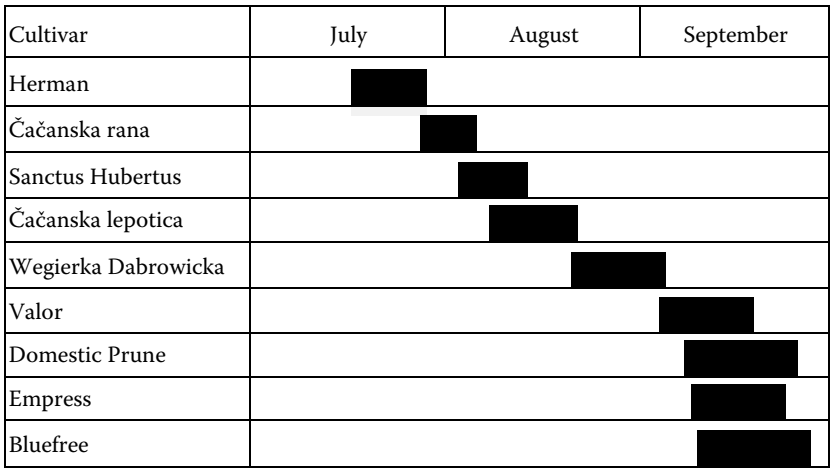

Fig. 1. Duration of fruit ripening period of different cultivars

potica but it was mostly visible in Sanctus Hubertus whose trees grafted onto Wangenheim grew less than half compared to those grafted onto Myrobalan.

Tree canopy

The final canopy volume in this experimental orchard fluctuated around 6 m^3 and it was kept in the size by restricted pruning onwards. Bluefree, Čačanska rana, Herman and Sanctus Hubertus, grafted onto Myrobalan, reached the final size already in 2002, whereas Wegierka Dabrowicka grafted onto Wangenheim, in 2006, was the latest one (Table 1).

The highest canopy densities were recorded in cultivars Domestic Prune and Sanctus Hubertus, whereas Bluefree and Čačanska lepotica were the most sparse ones (Table 2). Differences between rootstocks on this trait were generally negligible with exception of Čačanska lepotica whose trees grafted onto Myrobalan were significantly more dense in comparison to those grafted onto Wangenheim. Except of Bluefree, all tested cultivars spurred well and the rootstocks showed no influence on this characteristic. Regarding branch setting, differences between cultivars were also relatively small. Their mean shift angle from vertical level (when the branches were the most bent downwards) was the smallest in Čačanska rana on Wangenheim. On the contrary, branches of Bluefree on Wangenheim appeared the most upwards. The same cultivar was also distinguished by the most excessive bare branch area, followed in this performance by Čačanska lepotica. This characteristic does not seem to be influenced at all by the rootstock used.

Productivity

Results of total yield evaluation in this trial are shown in Table 3. Cv. Valor grafted onto Myrobalan reached the highest annual yield accounting 15 kg per tree which corresponds to 20 t/ha. Yields slightly lower (19.4 t/ha) were recorded on trees of Wegierka Dabrowicka grafted on the same rootstock. Both cultivars had also the highest yield values as the trees were grafted onto Wangenheim rootstock (17.4 and 17.7 t/ha respectively, or 13.3 and 13.1 kg/tree, respectively). Cv. Valor grafted onto Myrobalan rootstock achieved the highest yield per one harvest harvest-season, accounting nearly 40 kg/tree. A significantly lower maximum harvest

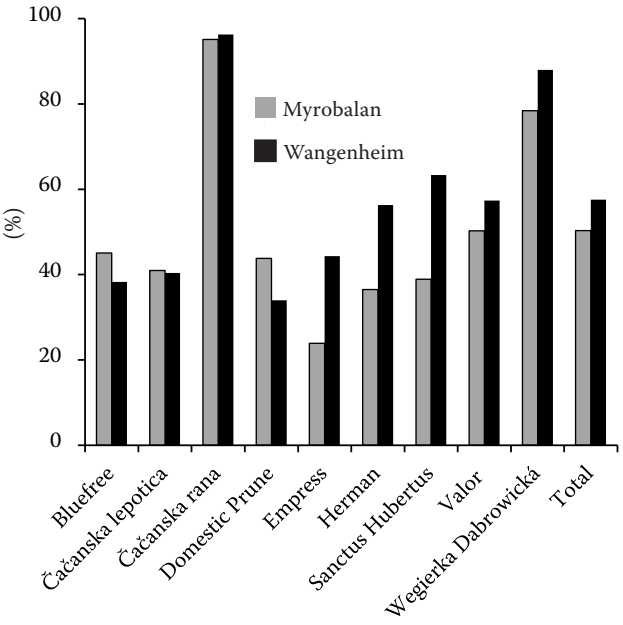

Fig. 2. Tendency for biennial bearing expressed by mean percentage of harvest drop from 4 years with the highest yield depression in comparison to its level in previous year

value was evidenced by other productive cultivars, Wegierka Dabrowicka and Domestic Prune. The lowest yields were recorded on trees of Bluefree and Čačanska rana.

Wegierka Dabrowicka on both rootstocks was distinguished from other cultivars by the highest yield efficiency with values > 3 kg/m^3. It was followed in this important characteristic by Valor and Empress. On the other side, Čačanska rana and Bluefree showed the smallest values, roughly half of the highest. Yield efficiency of trees grafted onto Wangenheim rootstock was generally higher than of those grafted onto Myrobalan but the difference was the highest on Domestic Prune (~25%).

Time of flowering and harvest ripening

Start of flowering within this study fluctuated from April 11 till May 6 (Table 4). The earliest to bloom were Wegierka Dabrowicka and Čačanska rana whereas the Domestic Prune was the latest one. The average difference between the phenological phases within these cultivars was 7 days. Time of flowering appeared not to be influenced by rootstock.

The mean time of fruit ripening season according to cultivars is shown in Fig. 1. The season, defined by the beginning of ripening period, started with Herman in the middle of July and finished with Bluefree at the end of the first decade of September. The harvest season of early ripening cultivars was generally shorter then the latest ones. The earliest fruit ripening time in this study was recorded on July 4th in Herman and the latest on September 20th in Bluefree (Table 4). The mean fruit ripening period in this study accounted 27 days; the shortest appeared in Čačanska lepotica and Wegierka Dabrowicka (21 days), the longest one in Sanctus Hubertus (39 days).

Regarding to fruit developing period (from blooming to harvest), the shortest was recorded in Herman: the average value was 85.5 days, with a minimum of 77 days. On the opposite, trees of Bluefree grafted onto Wangenheim showed the longest fruit development period (141.4 days on the average with a maximum of 149 days).

Table 4. Dates of tree flowering, of fruit ripening time and length of fruit development period according to cultivars and rootstocks

Cultivar	Rootstock	Start of tree flowering			Start of fruit harvest ripening			Number of days from flowering till start of harvest ripening		
		Ø 2001–2010	min	max	Ø 2001–2010	min	max	Ø 2001–2010	min	max
Bluefree	Myrobalan	23/4	15/4	3/5	8/9	23/8	20/9	140.6	133	146
	Wangenheim	22/4	15/4	3/5	8/9	23/8	20/9	141.4	133	149
Čačanska lepotica	Myrobalan	20/4	15/4	30/4	5/8	22/7	12/8	105.3	98	115
	Wangenheim	20/4	15/4	1/5	6/8	22/7	12/8	105.4	98	117
Čačanska rana	Myrobalan	18/4	12/4	1/5	25/7	12/7	5/8	97.5	88	106
	Wangenheim	19/4	12/4	30/4	26/7	12/7	4/8	98.3	88	105
Domestic Prune	Myrobalan	25/4	17/4	4/5	6/9	20/8	16/9	135.0	129	141
	Wangenheim	25/4	17/4	6/5	4/9	18/8	16/9	133.9	129	141
Empress	Myrobalan	21/4	11/4	1/5	6/9	22/8	19/9	141.3	125	149
	Wangenheim	20/4	11/4	1/5	6/9	19/8	19/9	142.2	125	151
Herman	Myrobalan	21/4	15/4	1/5	16/7	4/7	29/7	85.7	79	92
	Wangenheim	21/4	15/4	1/5	16/7	4/7	29/7	85.5	77	93
Sanctus Hubertus	Myrobalan	20/4	15/4	1/5	1/8	16/7	24/8	99.0	92	116
	Wangenheim	20/4	15/4	1/5	31/7	16/7	24/8	96.9	92	103
Valor	Myrobalan	22/4	15/4	4/5	3/9	20/8	15/9	135.5	122	149
	Wangenheim	21/4	15/4	4/5	2/9	20/8	15/9	134.3	122	151
Wegierka Dabrowicka	Myrobalan	18/4	11/4	1/5	18/8	8/8	29/8	120.9	114	136
	Wangenheim	18/4	11/4	1/5	20/8	8/8	29/8	123.1	114	137
Average	Myrobalan	21/4	14/4	1/5	16/8	6/8	25/8	117.9	112	125
	Wangenheim	21/4	14/4	2/5	16/8	6/8	25/8	117.5	111	126

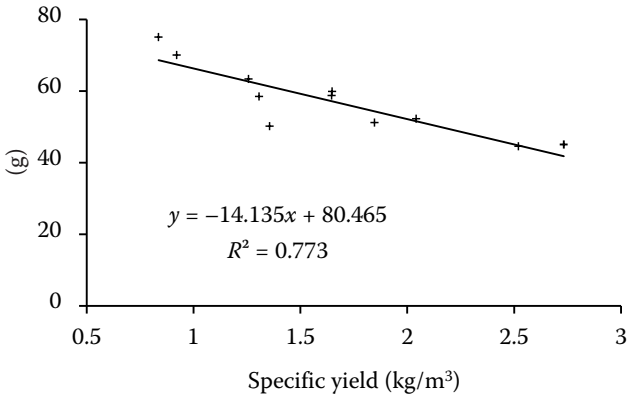

Fig. 3. Relationship between yield efficiency and fruit weight of cv. Bluefree trees grafted onto Wangenheim seedling rootstock

Alternate bearing

Cultivar Čačanska rana had the highest tendency to alternate bearing in this study (Fig. 2). This undesirable character was also exhibited on cultivar Wegierka Dabrowicka. On the contrary, trees of Empress had the most regular bearing habit. As regards the rootstock influence, Wangenheim slightly increased an alternate bearing habit on Empress, Herman and Sanctus Hubertus.

Fruit size

The average fruit weight for all the cultivars on test grafted on both the rootstocks are showed in Table 5. The heaviest fruits were recorded in Bluefree (~58 g on the average). Fruits of this cultivar were the biggest in 2010 on trees grafted onto Wangenheim having mean fruit of 75.1 g (data not showed). Fruits of Empress had a similar behaviour; 52 g on average and a maximum record of 69.8 g (data not shown). On the third position in a decreasing order Čačanska rana was classified (51 g on the average) that was followed by Valor with an average fruit weight 3 g smaller (~48 g on the average) while its largest fruits were 58.4 g on trees grafted onto Wangenheim in 2002 (data not shown). On the contrary, Domestic Prune had the smallest fruit weights, ranging around 19 g on the average and reaching a maximum size around 26.4 g on Wangenheim rootstock in 2009 (data not shown).

The fruit weight was strongly dependent on the yield level only in cv. Bluefree especially as they were grafted onto Wangenheim rootstock (Fig. 3). The relationship appeared much weaker on trees of cv. Empress (Fig. 4). This behaviour was not found in any other of the assessed cultivar/rootstock combinations.

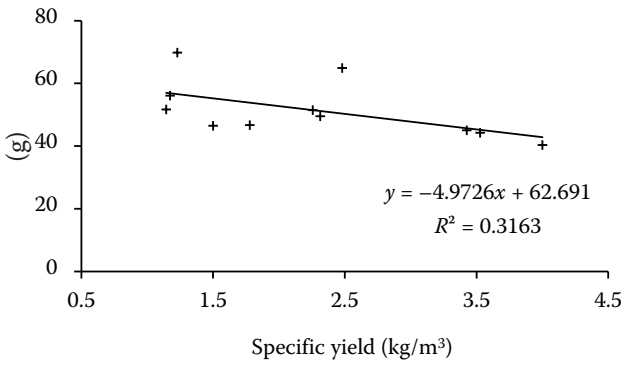

Fig. 4. Relationship between yield efficiency and fruit weight of cv. Empress trees grafted onto Wangenheim seedling rootstock

Harvest season

The early cultivar Čačanska rana had the shortest harvest season, accounting to 9 days on the average with its minimum of 6 days (Table 5). Only two days longer were Sanctus Hubertus and Herman grafted onto Wangenheim. Herman was the only exception since the rootstock significantly influenced the duration of the harvest season. On the other hand, Empress and Domestic Prune evidenced the longest harvest season accounting on the average to 18 days.

DISCUSSION

In comparison to the results recorded during the first period of testing (Blažek et al. 2004), Sanctus Hubertus grafted onto Myrobalan showed the most vigorous behaviour. Similarly, Bluefree was the medium vigorous at the initial period while it was clearly classified as the least vigorous at the end. In a similar way, Wegierka Dabrowicka was the weakest growing cultivar at the beginning of the trial while it finally reached a medium level. Regarding yield efficiency a considerable difference of Domestic Prune final rating (especially as it was grafted onto Wangenheim) in comparison to its values accounted at the fist years of the study was observed. These findings strongly confirm the necessity to evaluate some traits for longer time in similar trials.

Table 5. Influence of cultivars and rootstocks on fruit weight and fruit ripening duration

Cultivar	Rootstock	Mean fruit weight (g)			Period of fruit harvest ripening			
					mean date of the start	number of days		
		Ø	min	max		Ø	min	max
Bluefree	Myrobalan	57.9	45.2	115.9	8/9	15.3	13	17
	Wangenheim	57.8	44.6	115.6	8/9	14.8	12	17
Čačanska lepotica	Myrobalan	39.0	33.6	78.1	5/8	13.6	10	18
	Wangenheim	37.8	27.7	75.7	6/8	14.3	11	17
Čačanska rana	Myrobalan	51.1	40.2	102.2	25/7	9.2	6	15
	Wangenheim	50.4	36.5	100.9	26/7	8.9	6	13
Domestic Prune	Myrobalan	18.8	16.8	37.5	6/9	17.7	15	21
	Wangenheim	19.2	16.2	38.3	4/9	18.4	15	21
Empress	Myrobalan	51.9	44.3	103.8	6/9	18.1	14	23
	Wangenheim	52.1	40.3	104.2	6/9	18.0	14	24
Herman	Myrobalan	28.0	22.0	56.0	16/7	13.4	10	16
	Wangenheim	28.4	23.4	56.7	16/7	11.2	7	15
Sanctus Hubertus	Myrobalan	28.2	23.2	56.3	1/8	10.6	8	14
	Wangenheim	28.4	25.1	56.9	31/7	11.3	7	15
Valor	Myrobalan	46.5	37.2	93.1	3/9	12.0	9	15
	Wangenheim	47.8	37.6	95.7	2/9	11.9	9	15
Wegierka Dabrowicka	Myrobalan	27.4	23.2	54.9	18/8	13.7	9	17
	Wangenheim	26.9	20.0	53.8	20/8	14.4	10	18
Average	Myrobalan	39.0	34.4	78.0	16/8	13.7	10.4	17.3
	Wangenheim	39.2	35.2	78.4	16/8	13.7	10.1	17.2
LSD (P = 0.05)	Myrobalan	2.5						
	Wangenheim	2.1						

The dwarfing effect of Wangenheim Prune seedling was found in this study on the same level as reported from Poland (Rozpara, Grzyb 1998; Sitarek et al. 2004; Świerczynski, Stachowiak 2009) only in the case of Sanctus Hubertus cv. On the contrary, its effect was rather negligible in Empress and Čačanska lepotica. This phenomenon could be partly influenced by more restricted tree pruning applied in this study for some cultivars grafted onto Myrobalan rootstock due to a strongly limited tree spacing (Sosna 2010). Another reason could be the higher planting density used in this study in which root systems are primarily located within the herbicide strip (Black et al. 2010).

Different effect of the rootstocks on tree vigour in particular cultivars, which was observed in this study, is in agreement with previous finding of Kosina (2004).

According to the general results, Wangenheim rootstock should be recommended for modern planting of cultivars Bluefree, Domestic Prune, Sanctus Hubertus, Valor and Wegierka Dabrowicka. Within these cultivars, our results are more or less in agreement with earlier findings (Rozpara, Grzyb 1998). A specific positive effect of the rootstock on yields, and partly also on fruit size, of some cultivars was also reported by Hrotkó et al. (2002). But our findings, showed that rootstock does not influence fruit size in the majority of cultivars, in agreement to the results of Kosina (2004).

Tree spacing used adopted in this study (5 × 1.5 m) seems to be more or less adequate for most cultivar – rootstock combinations that were tested. Greater distances among trees like 6 × 2.5 m should be recommended for Sanctus Hubertus, Čačanska rana and Herman if Myrobalan rootstock is adopted. Planting distance of Čačanska lepotica on both rootstocks should not be much smaller – probably 6 × 2 m. On the contrary, Bluefree could be planted

in a smaller spacing up to 4 × 1 m especially if trees are grafted onto Wangenheim rootstock.

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